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Measuring the national economic benefits of reducing livestock mortality

Stephen L. Ott *, Ann Hillberg Seitzinger, William D. Hueston

Centers for Epidemiology and Animal Health, 555 S. Howes, Fort Collins, CO 80521, USA

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Abstract

A simple model for calculating the macroeconomic impact of improving livestock efficiency through better herd health is presented. Using economic surplus analysis with preweaning mortality in swine as the example, the model demonstrates the importance of improving livestock production efficiency in the face of international competition and how consumers gain from improved animal health. The model can be used to examine the appropriateness of expenditures on animal disease control programs and animal health research.

Keywords: Macroeconomic analysis; Swine; Preweaning mortality; Economic surplus

1. Introduction

Increasingly, the merits of disease control and herd health programs are subjected to economic analyses estimating the costs of disease and the benefits accruing from disease control or health improvement. Most published studies focus on individual animals or herds and have been presented as cost of disease surveys (Kaneene and Hurd, 1990; Miller and Dorn, 1990a,b; Sischo et al., 1990), benefit cost analysis using some type of decision analysis tool (Juste and Casal, 1993; Slenning, 1994; Rougoor et al., 1994), or marginal value of preventive practices (Miller and Bartlett, 1991). Even studies that analyze treatment of a whole country's herd sometimes assume fixed market prices (Stem, 1993; Bech-Nielsen et al., 1993). These estimates of costs and benefits, especially those of national scope, may create the misperception that reducing disease always benefits producers or that producers will recapture the entire value of their losses from disease. These studies fail to consider the market impacts of an increased supply of animals and animal products resulting from a reduction in disease.

* Corresponding author: Tel. (970) 490-7823; Fax. (970) 490-7899; e-mail sott@aphis.usda.gov.

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This paper will revisit animal health economics by measuring the national economic benefits which would accrue by reducing livestock mortality regardless of cause, taking into account the increased market supply available due to lower death loss. The approach differs from other manuscripts (Krystynak and Charlebois, 1987; Buhr et al., 1993; Crooks et al., 1994) by not requiring a large general econometric model or a very specialized epidemiological/economic model (Berentsen et al., 1992). Although applied to a specific example, reducing neonatal piglet mortality, our method can be adapted easily to other livestock commodities, variations in mortality levels, or even production losses due to morbidity.

2. Economic surplus theory

Economists often evaluate benefits to society of improved agricultural production efficiency by determining increases in economic surplus (Norton and Davis, 1981). Economic surplus is defined as the sum of benefits received by consumers (consumer surplus) and producers (producer surplus) (Just et al., 1982). Consumers benefit when the price they pay for a good or service—the market price—is below what they are willing to pay. This consumer benefit is called consumer surplus. Likewise, producer surplus captures the amount by which market prices exceed production costs. Changes in economic surplus can be used to measure the value to society of improving animal health, such as reducing neonatal piglet mortality.

Buhr et al. (1993) have explained how national economic surplus can be represented graphically using supply and demand curves. We expand upon their presentation by incorporating international trade into the model. The intersection of the supply and demand curves (Q_c, P_e), denotes the market clearing price and quantity in the absence of international trade (Fig. 1). In the presence of trade, the market clearing price will rest above P_e if the country is an exporter and below P_c if the country is an importer. In the importer case, Fig. 1 shows a market clearing price of P_m and a domestic quantity supplied of Q_s. Imports, Q_m, are equal to quantity demanded, Q_d, minus quantity supplied, Q_s. National consumer

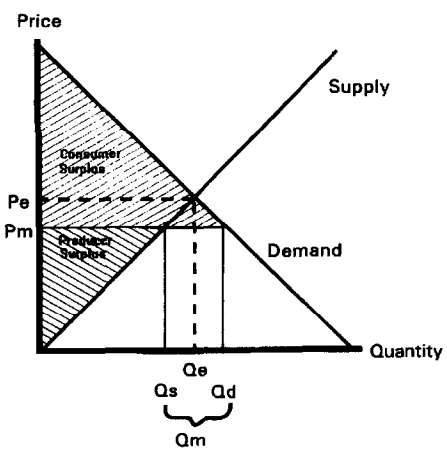

Fig. 1. Consumer and producer surplus in the importer case

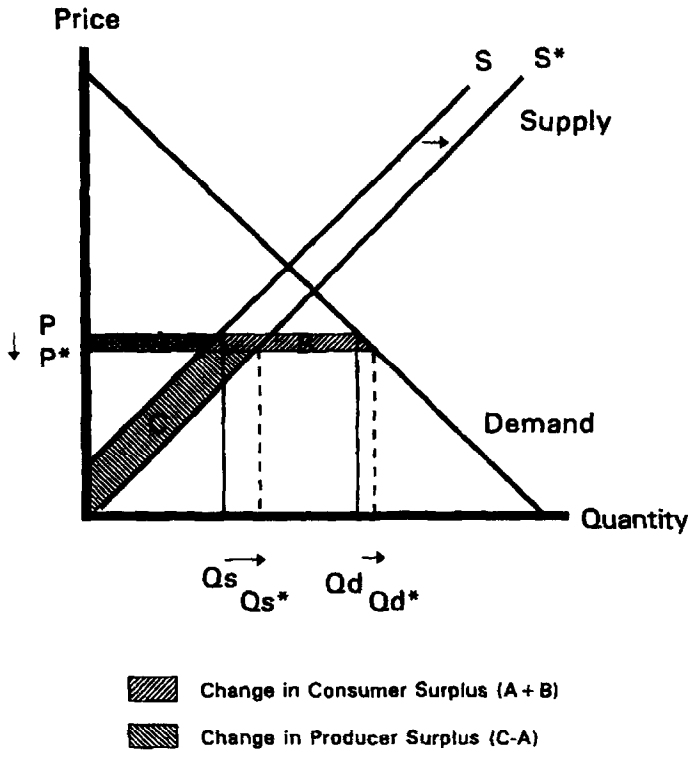

Fig. 2. Changes in consumer and producer surplus owing to a reduction in swine mortality.

surplus is the shaded area between the demand curve and the market price. National producer surplus is the dotted area between the supply curve and the market price. Thus, measuring national economic surplus requires an understanding of the supply and demand curve characteristics for a specific industry.

Improving animal health reduces per unit production costs, allowing producers to supply a greater quantity at a given price. This change is represented graphically by a rightward shift in the supply curve. The resulting changes in consumer surplus (area A + area B) and producer surplus (area C − area A) are shown in Fig. 2. Consumers benefit because they now can purchase a greater quantity at a lower price. Producers also benefit from being able to sell a larger quantity, but they now receive a lower price. In order for producers as a group to benefit, the larger quantity sold and savings from reduced production costs must offset the lower price received. For society, total surplus will always increase because the rise in consumer surplus (area A + area B) is always greater than the loss to producers (area A).

3. Modeling strategy

Reducing preweaning death loss lowers the per unit cost of raising animals. Collectively, farmers respond to lower costs and thus higher profit margins by increasing the supply of

meat. Calculating the change in economic surplus involves determining how the increase, or shift, in supply affects equilibrium price and quantity.

To determine such changes we adapted a model developed by Lichtenberg, Parker and Zilberman (LPZ) (1988) and revised by Forsythe and Corso (1994). The LPZ model assumes linear demand and supply functions and parallel supply shifts. Under the latter assumption, the magnitude of a supply shift equals the difference in average production costs associated with each mortality rate.

The LPZ model offers good approximations for small changes in price and quantity and in the case of an importer, the model consists of four equations.

$$MC^{s}(Q_s, a_s) = P \tag{1}$$

$$MC^{m}(Q_m) = P \tag{2}$$

$$D^{d}(Q_d) = P \tag{3}$$

$$Q_s + Q_m = Q_d \tag{4}$$

Eqs. (1) and (2) assume domestic and imported sources of supply, denoted Q_s and Q_m respectively, adjust output such that the marginal costs, MC^s and MC^m respectively, equal price, P. In Eq. (1), an additional shifter, a_s, represents the impact of reduced death loss on marginal cost. The third equation is a domestic demand function where the price consumers are willing to pay, P, is a function of quantity consumed, Q_d. The final equation requires the markets to clear—domestic and imported supplies must equal domestic demand. The impact of reduced mortality on the equilibrium price and quantities is obtained by totally differentiating the above equations and recognizing that the marginal cost function is the inverse supply function (Appendix).

4. Data sources

Data required for the LPZ model are minimal: demand and supply elasticities which quantify the responsiveness of producers/consumers to price changes, base equilibrium of price and quantity, and the change in average cost of production.

Prices and quantities in the model are at the farm gate. An average of 5 years of US data (1989–1993) were used to calculate the initial equilibrium. Quantity is liveweight sent to slaughter, and price is expressed in 1992 dollars per metric tonne. The estimated original market equilibrium is 10.3 million t of domestic production and 152 047 t imported with a price of \$1064 t^{-1} (USDA-ERS, 1994b).

An average of several reported elasticities was used to represent domestic demand and supply elasticities (Eales and Unnevehr, 1988; Lemieux and Wohlgenant, 1989; Moschini and Meilke, 1989; Brester and Wohlgenant, 1991). Although not all of these studies report farm level demand elasticities, farm level elasticities were derived by multiplying retail demand elasticities by the ratio of farm value to retail price (George and King, 1971). Between 1989 and 1993, US farmers received an average of 37% of the retail price for pork

(USDA-ERS, 1994a). These processes yield a farm level demand elasticity for hogs of −0.35 and a domestic pork supply elasticity of 0.4.

Elasticities with absolute value of less than 1 are said to be inelastic. Inelastic supply (demand), such as the case here, means that a change in production (consumption) due to a change in price will be less than proportional to the change in price (e.g. a 10% decline in price results in consumers buying only 5% more). Conversely, a change in quantity leads to a price change that is more than proportional. As a result, when producers produce more, the percentage decline in market price will be greater than the percentage increase in quantity. With price dropping more than quantity expanded, total revenues (expenditures) for producers (consumers) declines.

The elasticity of import supply, 3.0, was calculated based on the domestic supply and demand elasticities and the international market shares of the major pork importers and exporters (Ynetma, 1932; Bredahl et al., 1979).

Preventing preweaning mortality reduces average production cost by allowing producers to spread their fixed costs over a greater number of pigs. This cost reduction equals the shift in the supply curve. Fixed costs were obtained from USDA:ERS swine cost of production surveys for Midwestern farrow-to-finish producers. Fixed costs include general farm over-

Table 1
Changes in equilibrium hog price and quantity due to elimination of preweaning piglet mortality [a]

	Import adjustment allowed	Imports fixed
Original equilibrium	1065	1065
Price ($ t^{-1}) [b]	10255	10255
Quantity produced (10^3 t) [c]	152	15
Quantity imported (10^3 t) [d]		
Change in production costs ($ t^{-1})	−29	−29
New equilibrium		
Price ($ t^{-1})	1050	1049
Quantity produced (10^3t)	10312	10308
Quantity imported (10^3t)	146	152
Change in price ($ t^{-1})	−15	−16
Change in production (10^3 t)	56	53
Change in imports (10^3 t)	−6	0
Annual dollar changes ($1000)		
Producer receipts	−90684	−103024
Producer costs	−240659	−244136
Producer surplus	149975	141112
Consumer surplus	152274	161265
Economic surplus	302249	302377

[a] Totals may not sum owing to rounding error.
[b] At the farm gate.
[c] Live slaughter weight.
[d] Carcass weight converted to liveweight.

head, property taxes, insurance, and capital replacement. Cost savings from fewer preweaning deaths equals new fixed costs minus old fixed costs, where the new fixed costs are set equal to old fixed costs multiplied by the ratio of old number weaned to new number weaned. The 5 year average fixed costs are \$195 t^{-1} (USDA-ERS, 1994b). With an average number weaned of 8.4 per litter and 1.5 deaths per litter (USDA:APHIS, 1992), the shift in pork supply from preventing all preweaning deaths equals \$29.18 t^{-1}. This figure differs from Crooks et al. (1994) where a 1% decrease in mortality is cited as leading to only a 0.06% reduction in costs and thus is assumed to be zero. Here, the calculated cost of production decline from a 1% drop in mortality is 0.15%.

5. Results

Reducing production costs by \$29.18 t^{-1} results in a \$14.60 t^{-1} (1.4%) decline in price and an increase of 50 000 t (0.5%) in the quantity of pork consumed (Table 1). Consumer surplus increases by \$152.3 million, with \$152.0 million coming from the price savings on the quantity previously purchased. The remaining \$0.3 million comes from additional purchases.

Producer surplus increases by \$150.0 million as reduced production costs of \$240.7 million exceed lost producer receipts of \$90.7 million. Domestic producers increased their marketings by 56 000 t not only by meeting increased demand but also by displacing 6000 t of imported pork.

Change in economic surplus is the sum of the changes in consumer and producer surplus and equals \$302.2 million. The estimated changes in producer receipts, cost of production,

Table 2
Changes in equilibrium hog prices and quantities for different levels of reduction in preweaning mortality [a]

	Reduction in preweaning mortality (piglets per litter)					
	0.25	0.50	0.75	1.00	1.25	1.50
Change in cost (\$ t^{-1})	−4.93	−9.86	−14.79	−19.72	−24.65	−29.58
Change in price (\$ t^{-1}) [b]	−2.47	−4.93	−7.40	−9.86	−12.33	−14.80
Change in production (t) [c]	9492	18985	28477	37970	47462	56954
Change in imports (t) [d]	−1056	−2113	−3169	−4226	−5282	−6338
Net change in quantity (t)	8436	16872	25308	33744	42180	50616
Annual dollar changes (\$1000)						
Producer receipts	−15206	−30459	−45758	−61105	−76498	−91938
Producer costs	−40486	−81044	−121672	−162369	−203137	−243975
Producer surplus	25281	50585	75913	101264	126639	152036
Consumer surplus	25767	51372	77089	102827	128586	154366
Economic surplus	51047	101957	153002	204092	255225	306403

[a] Totals may not sum owing to rounding error.
[b] At the farm gate.
[c] Live slaughter weight.
[d] Carcass weight converted to liveweight.

consumer surplus, and economic surplus are approximately linear to the number of piglets saved per litter (Table 2).

The increased litter size which results from decreasing preweaning mortality reduces the number of farrowings needed to produce the pork demanded even though total pork production rose. With no preweaning mortality, the number of farrowings required to meet the nation's pork needs would decline by 1.6 million or 14.5%.

We also ran the model with imports held constant. The difference in economic surplus between the two models is less than 0.1% (Table 1). However, there is a difference in how the surplus is divided between consumers and producers. Holding imports constant shifts more of the benefits towards consumers as price must decline more in order to market the extra quantity produced.

Changes in economic surplus also measure how many additional resources can be applied to prevent preweaning piglet mortality. On a per piglet born alive basis, the model estimates that producers could afford to spend $1.42 to eliminate all mortality. Consumers have a still greater incentive to save preweaned piglets as their increase in surplus is greater then that of producers. This suggests that consumer expenditures for activities which reduce mortality, such as animal disease research, are warranted.

Appendix A: Equations defining changes in price, quantities and consumer and producer surplus

(1) Change in price

$$dP = \frac{MC_a^s da_s e_s Q_{s0}}{e_s Q_{s0} + e_m Q_{m0} - e_d Q_{d0}}$$

(2) Change in domestic quantity supplied

$$dQ_s = \frac{(dP - MC_a^s da_s) e_s Q_{s0}}{P_0}$$

(3) Change in import quantity supplied

$$dQ_m = \frac{dP e_m Q_{m0}}{P_0}$$

(4) Change in domestic quantity demanded

$$dQ_d = \frac{dP e_d Q_{d0}}{P_0}$$

(5) Change in producer surplus

$$dPS = P_1 Q_{s1} - P_0 Q_{s0} - MC_a^s da_s Q_{s0} - P_1 dQ_s + \frac{P_0 dQ_s^2}{2 e_s Q_{s0}}$$

(6) Change in consumer surplus

$$dCS = dPQ_{d0} + 0.5dPdQ_d$$

where CS is consumer surplus, e_d is elasticity of domestic demand, e_s is elasticity of domestic supply, e_m is elasticity of import supply, MC is change in marginal cost, P_t is price at time t, PS is producer surplus, Q_{dt} is quantity demanded at time t, Q_{st} is quantity supplied domestically at time t and Q_{mt} is quantity imported at time t.

If one wants to consider the domestic market only, then $e_m Q_{m0}$ in Eq. (1) equals zero and all other appendix equations remain the same.

Steps in applying these equations

(1) Decide upon demand and supply elasticities. Several articles listed in the reference report elasticities.

(2) Determine base equilibrium price (P_0), domestic quantity supplied (Q_{s0}), and quantity imported (Q_{m0}). We used 5 year averages.

(3) Calculate change in production cost ($MCSAI$as/$SAIda_s$) which represents the shift in the supply curve. With a parallel supply shift, average production costs, such as those from cost of production surveys or farm record keeping bureaus, may be used.

(4) Use the above information in Eq. (1) to determine the change in price (dP).

(5) Use the resulting change in price in Eqs. (2)–(4) to ascertain adjustments in domestic quantity supplied, import quantity supplied, and domestic quantity demanded.

(6) Incorporate price and quantity information to determine changes in cash receipts and production costs (Eq. (5)). The sum of changes in cash receipts and production costs equals change in producer surplus.

(7) Calculate difference in consumer surplus by incorporating price and quantity changes into Eq. (6).

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